An Investigation of Methods for Including Ecosystem Requirements in Order of Approval (Study 5)

FINAL

April 2011

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Acknowledgements

We would like to express our thanks to the following people for their assistance in developing this report: John Arterburn of the Confederated Tribes of the Colville Reservation, Fish and Wild Life Department for providing fisheries requirements related input and Jerry Mitchell, Kristina Robbins, Safford Kirk and Orville Dyer from the BC Ministry of Environment for providing habitat requirements

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Executive Summary

Osoyoos Lake is one of several glacial-relic lakes in the bottom of the Okanagan Valley. These lakes help support regional biodiversity by mitigating annual temperature fluctuations and providing unique habitats, particularly riparian areas, adjacent to the lake and wetlands above and below the lake. There are three major categories of species that need to be considered in managing the Osoyoos Lake basin. They are:

- Invasive species in the lake and surrounding wetlands
- Protected, endangered or declining native species using the riparian and wetland areas adjacent to the lake
- Salmonids using the lake and the stream channel below the Zosel dam spillway.

The geographic distribution of these groups of species requires that considerations for determining lake level and discharge take into account impact on the lake, riparian areas and their associated wetlands, and the downstream in-channel habitat in the reach of the Okanogan River between the outflow of Zosel dam and the confluence with the Similkameen River. When lake level rises above 912.5 ft (278.1 m), waterfront property, beaches and riparian wetlands can be flooded. Periodic and gradual flooding of wetlands can be beneficial for some wetland species; however rapid changes in lake level and sustained high levels that cause shoreline erosion are not favorable for most riparian and wetland plants in need of protection. Discharge from Lake Zosel is critical to salmonid populations downstream of the lake. Because there is little evidence of significant populations of shoreline spawning salmonids in Osoyoos Lake, discharge, and not lake level, is the most important criteria for maintaining healthy salmonid populations in the lake.

Downstream of Zosel dam, water releases have the most impact on habitat in the reach between the dam spillway and the confluence with the Similkameen River. Below the confluence, the in-stream discharge is dominated by outflow from the Similkameen. Because salmonid spawning and incubation occurs in this reach during most of the year, discharge from the dam needs to be maintained year-round at a minimum level to support salmon redds. Under current conditions this discharge is close to the recommendations made by the Washington Department of Ecology of ~300 cfs (8.5 m^3/s). Additionally, discharges over 1,500 cfs (42.5 m^3/s) should be avoided to prevent harmful shoreline erosion.

There will be trade-offs between management strategies to conserve native species with different habitat needs as well as to control invasive species in the lake and downstream of the dam, and these strategies in turn may not converge with each other or with other goals for the lake. Management goals that will have to be developed from a prioritized list of species that the lake should be managed for (either to promote or control) and habitats prioritized for protection before specific management plans can be developed that take trade-offs into consideration .

Recommendations

- Lake levels could be fluctuated to control invasive species in the lake and riparian area. However, the levels required for this type of management are likely to cause serious problems for threatened species in shoreline habitats, and will also be in conflict with other criteria for lake management such as shoreline maintenance and recreation needs. Using lake level management for invasive species control is not practical in this setting and alternative methods, such as biological or chemical controls, should be explored first.
- Water quality in the lake is an important criterion for in-lake habitat. Particularly, bank erosion should be limited to avoid raising water turbidity and suitable oxygen conditions must be maintained in the lake during the late summer for cold water fishes. Lake level management is unlikely to solve the mid-summer low oxygen problem and other, well-documented methods should be employed as a primary solution.
- Lake levels impact riparian habitats that are important for threatened animal species such as the Tiger salamanders and Yellow-Breasted Chat. There is currently limited information available on the extent and elevation range of wetlands associated with species sensitive to changes in wetland attributes and area. Wetlands surrounding Osoyoos Lake, including those in Haynes Point Provincial Park may be maintained with a lake level plan that minimizes shoreline erosion and requires only gradual fluctuations in lake level. This type of operation may also help slow the spread of some invasive plant species. Because an upper lake level of 912.5 ft (278.1 m) has been maintained in recent years, wetland plants have adjusted to this level and it is a reasonable target for future management until more vegetation mapping can be conducted.

- The fisheries and in-stream flow demands are the largest component of the total water demand for Osoyoos Lake. Dam managers should continue to strive to meet fisheries demands recommended by the Washington Department of Fish and Wildlife. A target discharge range of ~300 – 1500 cfs (8.5-42.5 m^3/s) year-round should be used to maximize salmonid spawning habitat, maintain oxygenated conditions for redds while minimizing sediment transport and redd disturbance during high flows. Completion of downstream mitigation structures may change the lower end of the range of discharges needed downstream.
- Critical to managing for organisms using habitats in and near Osoyoos Lake is a clear understanding of exactly where these organisms are and how they use habitats over time. Detailed habitat maps for threatened species as well as invasive species that also provide fine-scale topographic information need to be developed.
- There are trade-offs between different management scenarios that will benefit various groups of species. Flow parameters should be set based on a prioritized list of goals for sensitive species.

1 Introduction

Osoyoos Lake is part of the Canadian Okanagan River Basin in British Columbia (BC), and the United States (US) Okanogan River Basin in Washington (WA). Zosel Dam is located on the Okanogan River near the city of Oroville in north central Washington State. The dam is downstream of Osoyoos Lake, which stores water for irrigational, domestic, recreational, and fishery uses (Washington State Department of Ecology, 1990). Osoyoos Lake is part of the Canadian Okanagan River Basin in British Columbia (BC), the United States (US) Okanogan River Basin in Washington (WA), and the Similkameen River Basin (Figure 1). Zosel Dam has four spillway gates with a total capacity of 3,000 cubic feet per second (cfs) (85 cubic meters per second (m^3/s)) and two fish ladders (WA State Department of Ecology, 1990). The Oroville Tonasket Irrigation District operates the dam under contract with the WA State Department of Ecology (1990), which has the direct responsibility over the dam. The International Joint Commission, under the Boundary Waters Treaty of 1909 prescribes the allowable levels of Osoyoos Lake in Canada and the United States in an Order of Approval. The International Joint Commission appoints a six member (three from US and three from Canada) International Osoyoos Lake Board of Control to supervise the implementation of the provisions of the Order of Approval (www.ijc.org). The current Order of Approval will terminate on February 22, 2013.

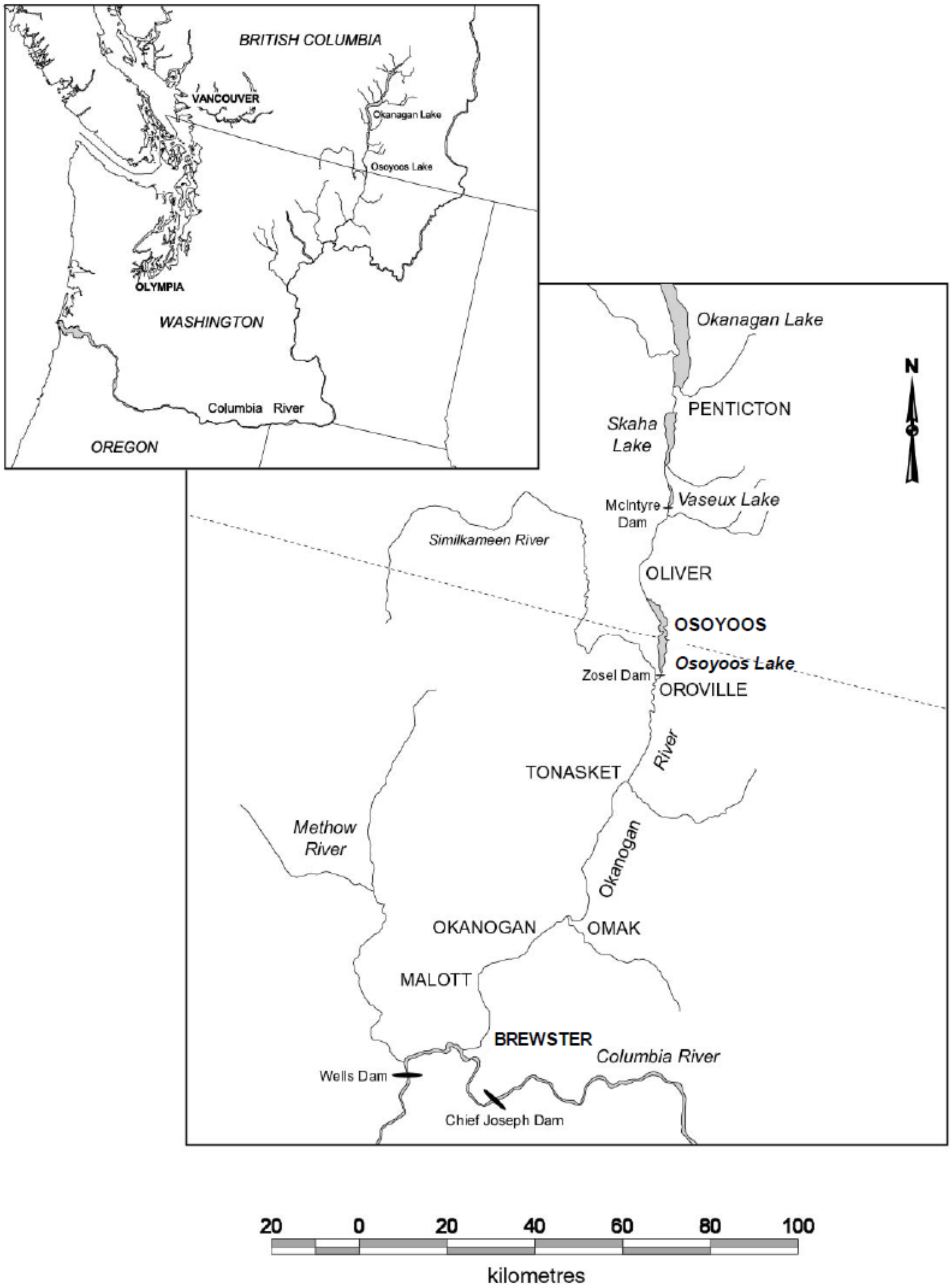

Figure 1. Map of Osoyoos Lake including Okanagan River (BC), Okanogan River (US), and Similkameen River (Glenfir Resources, 2006).

2 Study Objectives

The overall objectives of this study, as indicated in the original scope of work, was to analyze existing information on fish, wildlife and plant species that demonstrate sensitivity to Osoyoos Lake water level regulation by Zosel Dam and to answer the key questions outlined below. After a background section on historical water quality in Osoyoos Lake, these specific questions are addressed in individual sections of this report.

- Which plants and animal species of special importance are affected by the operations of Zosel Dam?
- How and when are these species affected?
- Are there ways of lessening or mitigating these impacts and are there ways of improving conditions for some species with changes in outflows at Zosel dam and different lake levels?
- Are there gaps in the present information base that need to be filled in order to understand the effect of water regulation on Osoyoos lake ecosystems?

3 Background

Osoyoos Lake is one of several glacial-relic lakes in the bottom of the valley. These lakes help support regional biodiversity by mitigating annual temperature fluctuations and providing unique habitats, particularly riparian areas, adjacent to the lake and wetlands above and below the lake (Iverson et al. 2008). The Okanagan Basin is also part of the Pacific Flyway, a trans-continental corridor that is a main spring and fall migration route for many species of birds (Erskine 1964, Lincoln et al. 1998).

In a 2008 report the Canadian Wildlife Service produced an inventory of sensitive ecosystems in the Okanagan Basin. That project included the lower elevation ecosystems from just north of Vernon south to the U.S. Border including part of the Similkameen Valley and some middle and upper elevation ecosystems in the South Okanagan (Iverson et al. 2008). Osoyoos Lake ecosystems are included in the South Okanagan region, and lower elevation ecosystems are the ones pertinent to lake management.

Osoyoos Lake levels are currently managed between elevations of 909 ft (277 m) and 913 ft (278 m). The Oroville Tonasket Irrigation District operates and manages Zosel Dam as per Condition 7 of the 1982 Order of Approval to the extent possible, thereby keeping Osoyoos Lake surface elevations between 911.0 ft (277.7 m) and 911.5 ft (277.8 m) from April 1 to October 31, except under drought conditions. Additionally, the order requires that Osoyoos Lake water levels should be maintained between 909 ft (277 m) and 911.5 ft (277.8 m) during the winter months (November 1 to March 31) (Figure 2). During drought years, the 1982 Order of Approval allows for the level of Osoyoos Lake to be raised to 913.0 ft (278.2 m) beginning April 1 to allow for additional storage for domestic use, irrigation use, and fish flows (Figure 2). Lake elevation must be returned to below 911.5 ft (277.8 m) by October 31.

When lake level rises above 912.5 ft (278.1 m), waterfront property, beaches and riparian wetlands can be flooded; a situation that concerns property owners and recreationalists. As a result, Ecology and BC Ministry of Environment typically enter into a non-binding memorandum of understanding during a drought year such that Ecology will not raise the lake above 912.5 ft (278.1 m), and in return the BC Ministry of Environment will release up to an additional 2,850 acre-feet (3.5 million m3) from Okanagan Lake in April or May to flush migrating sockeye salmon smolts out of Osoyoos Lake and downstream through Zosel Dam (International Osoyoos Lake Board of Control, 1994).

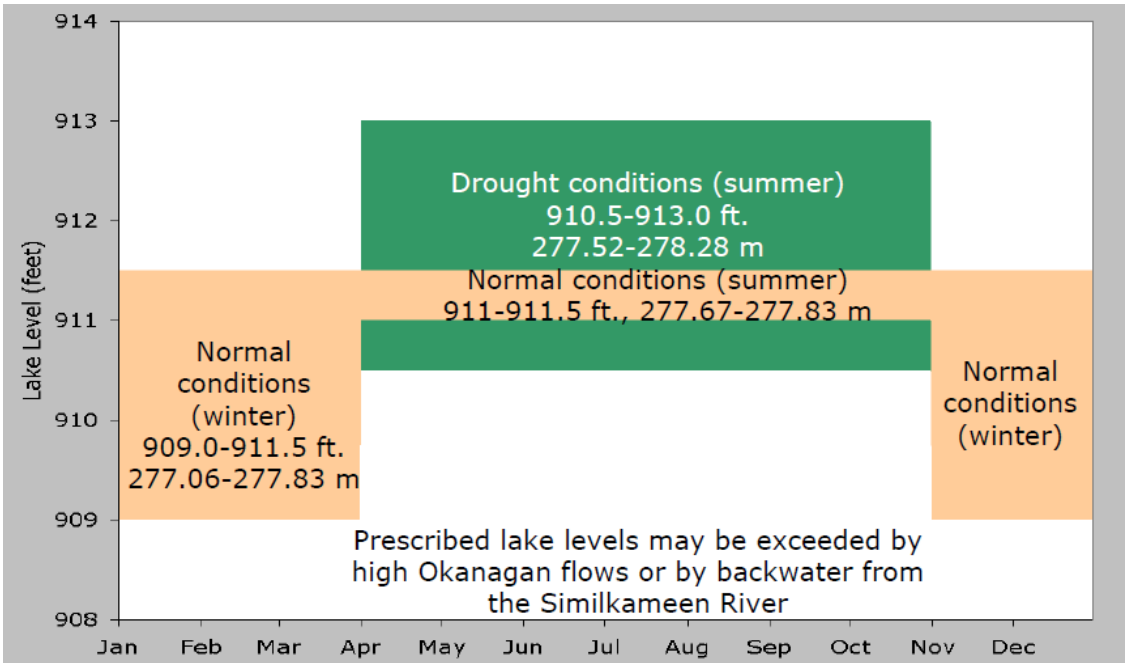

Figure 2. Diagram of the International Joint Comission Order of Approval for Condition 7 (tan) for normal water years and Condition 8 (green) for drought conditions (International Osoyoos Lake Board of Control, 2009).

The main confluence of the Similkameen River and the Okanogan River is ~ 3 miles downstream of Zosel Dam. At mile 1.25 (2.0 km) below the dam, a cross channel connects the two rivers and forms the north side of Driscoll Island (Figure 3). The topography of the area downstream of the dam is relatively flat with less than 10 ft (3.0 m) of elevation difference between the water elevation at the dam and the water surface at initial contact with the Similkameen. The flat topography means that fairly small changes in river stage can have large impacts on lateral movement of water. The mean annual flow in the Similkameen River is 3.5 times higher than the flow of the Okanogan River. During periods of very high flows in the Similkameen River, the river stage is higher on the Similkameen side and the flow direction in the Okanogan River can reverse, flowing back up the Okanogan River channel and overtopping Zosel Dam. When this condition occurs it is typically between Aprils and the end of June and can raise lake levels above 913 ft (278.2 m). Zosel dam cannot be operated to prevent this back flow from the Similkameen River.

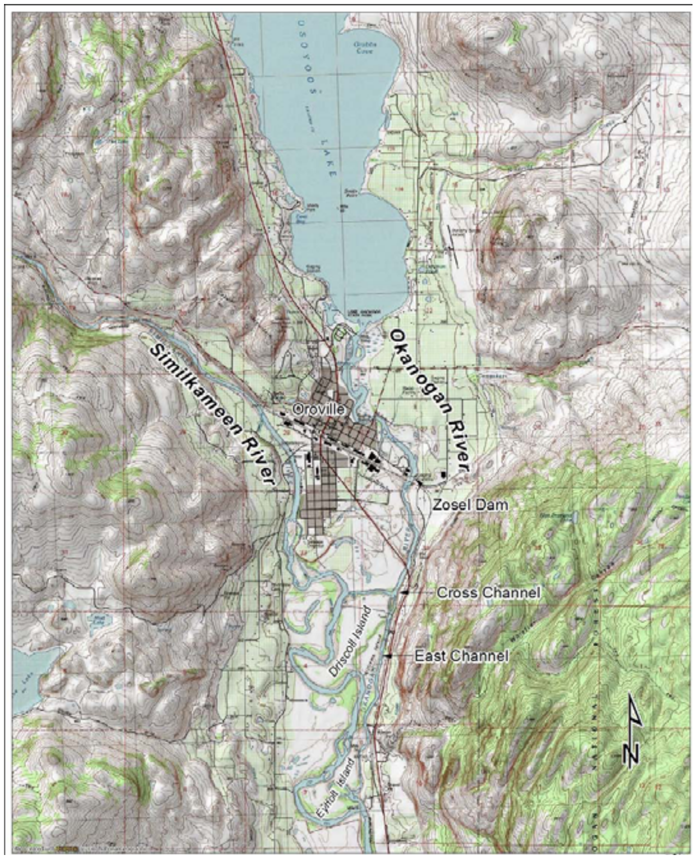

Figure 3. Map of Okanogan and Similkameen rivers showing the cross and east channels adjacent to Driscoll Island (LGL and PHES 2009).

4 Species of Special Importance

Species of special importance in the basin fall into three main categories. These are:

- Invasive species that need to be managed or removed
- Native wetland/riparian species populations that need to be promoted
- Fish species that need to be promoted

Invasive Species

An invasive species is one that that has since become a nuisance through rapid spread and increase in numbers, often to the detriment of other, native species. A recent survey by Glenfir Resources (2006) identified invasive species problematic in Osoyoos Lake as including; Eurasian Milfoil (*Myriophyllum sibericum*), Opossum Shrimp (*Mysis relicta*), Cattails (*Typha* *ssp.*), and Purple Loosestrife (*Lythrum salicaria*)**.** These are all common invasive species in northern North American aquatic habitats and have life history traits representative of many aquatic invasive species. Common strategies for suppressing aquatic, invasive species can include biological control, herbicide application, mechanical removal techniques, and physical management (Madsen 2000). Only physical management options were considered here as they can be controlled by dam operation.

Native species

We used the list maintained by the Osoyoos Lake Water Quality Society (http://www.olwqs.org/rarespecies.html, last accessed May 2010) as a starting point for choosing the species to focus on for this study. Table 1 is a list of endangered/threatened species from this source. We then determined species as relevant to this study as those that use habitats associated with Osoyoos Lake including: open water, ponds, shoreline, wetlands, and riparian areas. The Western Ridge Mussel (*Gonidea angulata)* was not included because it has not been seen in Osoyoos for at least 10 year (http://www.olwqs.org/rarespecies.html, last accessed May 2010). Biolinx Environmental Research Ltd and E. Wind Consulting (2004) notes that The Great Basin Toad occupies semi-arid grasslands, shrubby areas, open woodlands and uses ephemeral wetlands and is excluded from this study. Based on Osoyoos Species Accounts information obtained from Jerry Mitchell, Ministry of Environment, BC we added the Yellow Breasted Chat (*Icteria virens***)** to the list of species we considered in this study. We also look at four plant species identified by the BC Ministry of Environment as priority species: short-rayed aster (*Symphyotrichum frondosum),* scarlet ammannia (*Ammannia robusta*), toothcup (*Rotala ramosior*), and small-flowered lipocarpha (*Lipocarpha micrantha*).

Table 1. List of endangered/threatened species around Osoyoos Lake

Name	Type of Animal	Classification	Habitat
Tiger Salamander	Amphibian	Endangered	Wetlands, ponds, small lakes, grasslands
Sage Thresher	Bird	Endangered	Grassland, sagebrush shrub/steppe
Western Ridge Mussel	Crustacean	Endangered	Shallow waters and reeds along shoreline
Badger	Mammal	Endangered	Grasslands, Open forests
Great Basin Spadefoot Toad	Amphibian	Threatened	Dry grasslands, wetlands, small ponds
Great Blue Heron	Birds	Threatened	Wetlands, riparian woodland
Sandhill Crane	Birds	Threatened	Wetlands, Marshes
Sockeye salmon	Fish	Threatened	Deeper waters of Osoyoos Lake
Behr's Hairstreak Buttterfly	Insect	Threatened	Antelope/sagebrush grasslands
Nuttalls Cottontail Rabbit	Mammal	Threatened	Dry grasslands, open ponderosa pine forests
Antelope Brush	Plant	Threatened	Shrub/steppe, grasslands
Chocolate Lily	Plant	Threatened	Mid/high mountain slopes, forest floors
Toothcup	Plant	Threatened	Along lake shoreline
Gopher Snake	Reptile	Threatened	Grasslands, shrub/steppe, open ponderosa pine forest
Painted Turtle	Reptile	Threatened	Wetlands, small ponds
Western Rattlesnake	Reptile	Threatened	Cliffs, grasslands, forest
Yellow-bellied Racer	Reptile	Threatened	Grasslands, open forest, rock outcrops

Salmonids

Salmonids were included in our considerations due to their ecological and economic importance in the basin. Four groups were considered: Chinook (*Oncorhynchus tshawytscha*), Steelhead (*Oncorhynchus mykiss*), and the anadromous (sockeye) and non-anadromous (kokanee) subspecies of *Oncorhynchus nerka*. Fish surveys at the dam and redd count information indicates that depression of some runs of late-run chinook salmon in the mid-

Columbia River is cause for concern. Redd counts in the Okanogan and Methow Rivers have exhibited substantial declines since the late 1960s (Waknitz et al. 1995).

Genetic differentiation among sockeye salmon and kokanee populations indicates that kokanee have arisen from sockeye salmon on multiple independent occasions, complicating the relationship to sockeye salmon (Good et al. 2005). Kokanee in the Okanogan system evolved from Columbia River Sockeye and may be more closely related to that population than they are to kokanee in other basins (Foote 1989). They are thought to spawn primarily upstream of the lake in the reach between Osoyoos and Skaha Lake (Osoyoos Lake Water Quality Society). This reach is higher in elevation than can be influenced by changes in lake level of Osoyoos. Although kokanee are only occasionally observed in Osoyoos, the proximity of their upstream populations in Okanagan suggests they could be managed for in Osoyoos. Okanagan Lake supports stream spawning and lake shoreline spawning kokanee. Shore-spawners migrate to the lake from mid-October to mid-November (Levy 1991, Taylor et al. 1997) and require beaches along the lake shoreline to spawn.

5 Lake Level, downstream flow and habitat quality

As is described in Barber et al. (2010a), within stakeholder groups concerned with lake level elevation, the general consensus seems to be for lake levels of 912 or 912.5 ft (277.9 – 278.1 m) in summer months. One of the management challenges associated with maintaining lake levels at this height is shoreline erosion. Unconsolidated materials such as sands, gravels, and clays along the lake shoreline are susceptible to erosion. For waterfront landowners the largest impacts are land loss and water quality impairment due to increased sediment loading. However, the same forces act on natural riparian and wetland habitats as well. The severity of the erosion depends on several factors including shoreline slope, vegetation and soil composition. A number of studies suggest that near-bank wave heights of approximately 0.4 to 0.5 ft (0.12-0.15 m) mark the onset of bank sediment motion. Lake level influences the height of waves that come in contact with the shore and lower lake levels would decrease risk of erosion (Barber et al., 2010b).

Discharge at the dam, to the degree that it managed separately from lake levels, primarily impacts downstream habitats. The downstream impact on fish is two part; 1) flows required for fish health and migratory fish passage, and maintenance of in-channel habitat. 2) flow criteria in the dam operations procedure plan include fishery recommended values to promote the passage of migrating fish at Zosel Dam (Table 2).

Table 2. Zosel Dam Operating Procedures Plan summary of fish flows (Ecology 1990, please see Barber et al., 2010a for calculation details).

Discharge: Zosel Dam (cfs, m^3/s)	**Time period**	**Target species**	**Life stage**	**Location**
333, 9.43	Oct 1 – Apr 15	Chinook	egg/fry survival	downstream
482, 13.6	Mar 1 – Jun 15	Steelhead	spawning egg/fry survival	downstream
200, 5.66	June 15- Aug 1	resident fishery	all	downstream
Additional release:				
Pulse release: 2,850 acre-feet , 3.5 million m^3	April – timing determined each year	Sockeye	smolt	Flush from lake to downstream

Downstream of Zosel dam, dam releases have the most impact on habitat in the reach between the dam spillway and the confluence of the Okanogan River with the Similkameen River (herein after referred to as the “downstream reach”). Below the confluence, the in-stream discharge is dominated by outflow from the Similkameen. The Washington Administrative Code (WAC 173-549-020) established in-stream flow requirements at Oroville, WA in agreement with the U.S. Water Resources Act of 1971. These flows range from 320 cfs (9.1 m^3/s) from December through March to 500 cfs (14.2 m^3/s) in June at USGS gauge #12439500. Minimum in-stream flows are designed to provide the necessary flow to protect environmental, navigational and aesthetic attributes of the designated waterway (Ecology, RCW 90.54.020-3a). When this administrative code was developed, it was assumed that in-stream flows downstream of the confluence of the Okanogan and Similkameen Rivers would be met with flows from the Similkameen rather than flows from Osoyoos Lake due to the much higher discharges of the Similkameen.

6 Dam Regulation Impact on Species of Interest

Timing and flow rate of dam releases, combined with management of lake levels would ideally serve three goals 1) reduce invasive species 2) promote endangered species in riparian and wetland habitats and 3) increase salmonid populations.

6.1 Invasive species:

6.1.1 Eurasian Watermilfoil (*Myriophyllum sibericum*)

Several species of Watermilfoil including *sibericum* are common in this region and are a problem in Osoyoos Lake. Milfoil is a floating invasive species and is considered invasive because of its ability to form dense canopies that both shade out other species and cause difficulties for boaters and anglers. It is difficult to control because it is an adaptable plant and able to tolerate a variety of environmental conditions (Madsen 2000). Water level drawdown has been used successfully in multipurpose reservoirs to control aquatic plants, including Watermilfoil. In an attempt to desiccate and freeze the plants, drawdown is done in the winter to levels that expose the sediment surface. Summer drawdown has also been done to desiccate plants during hot weather. Results with this method are variable, and may need to be repeated every few years (Siver et al. 1986, Reclamation 2004). This method has been shown to cause significant, negative, impacts on some fish species and also riparian plant and animals, especially when drawdown is done in summer when shore habitat is exposed to hot/dry conditions.

6.1.1 Opossum shrimp (*Mysis relicta*)

Introduced to lakes outside of its native range, this relict crustacean typically occurs in cold water lakes. It is omnivorous, and as such it can greatly reduce food availability for fish such as kokanee salmon and small trout (Clarke et al. 2004). It also eats fish fry, further reducing fish populations. It is generally accepted that, once established, complete eradication is not feasible. Strategies to manage *Mysis* populations include both biological and physical controls. Because of its preference for cold, high oxygen environments, extreme drawdown of lake levels have be used to reduce *Mysis* populations. However, draw downs must produce warm, low oxygen or anoxic conditions to reduce shrimp populations (Martinez and Bergersen 1989). This strategy would obviously be detrimental to riparian and wetland organisms and would jeopardize the existing fishery.

6.1.1 Cattails (*Typha spp.*)

Cattails occur commonly in wetlands across North America. There are two major species as well as hybrids which are difficult to distinguish. These species are generally considered native to North America, however, cattails respond to human disturbance of wetlands and can produce dense, clonal growth and thick litter that can suppress other species and cause monocultures (Weson and Waring 1969). In these cases, cattails are considered invasive and a nuisance. Water level modification has been shown to be effective in controlling cattails in Northern wetlands. This requires flooding plants to a depth of 16-47” (1.2 m), for two years. Flooding following mechanical cutting requires significantly lower water depths (3-6” above plant height), however flood levels must be maintained for similar duration (Apfelbaum AES Cattail management 1985).

6.1.1 Purple Loosestrife (*Lythrum salicaria)*

Purple loosestrife is a rhizomatous perennial forb introduced to North America from Europe. Infestations are associated with wetland and marsh sites. Glenfir Resources (2006) identifies Purple loosestrife as having recently arrived in Osoyoos Lake and being a threat to native vegetation. Lythrum plants were brought to North America for flower gardens because of their striking color, ease of growth, winter hardiness, and lack of insect or disease problems. These hearty traits make control difficult. Purple loosestrife forms dense monotypic stands, and along with other invasive species such as Reed Canary Grass (*Phalaris arundinacea*), it displaces native wetland plants such as small-flowered lipocarpha (McIntosh 2010) causing the secondary problem of also displacing wildlife dependant on the native vegetation. Under optimum conditions, a small isolated group of purple loosestrife plants can spread extensively in a single growing season (Lym 2004). There is very limited evidence that cutting Purple Loosestrife stems and subsequently flooding the area so that cut plant stalks are completely immersed can be an effective control. However, flooding may also encourage the spread of purple loosestrife if a seedbank has already been established. This is the likely case if an infestation has been present for several growing seasons. Artificial flooding should not be used in high-quality natural communities (Smith 1993). Biological controls and chemical controls have been used effectively in controlling Loosestrife (Smith 1993, Lym 2004) and should be considered first before using lake level as a control. Similarly, the potential of spreading Loosestrife is larger with a fluctuating lake level and a more static lake level may be advantageous for preventing its spread.

6.2 Native animals

6.1.1 Tiger Salamander (*Ambystoma tigrinum melanostictum*)

Tiger Salamanders have been red listed by the province of British Columbia. It is an uncommon species in BC generally and is only known to exist in the region of the Okanagan and Lower Similkameen. It is in danger of extirpation due to its limited distribution, habitat loss, and vulnerability to introduced species (Warman et al. 1998). Tiger Salamanders use a variety of habitats at different points in their life cycle. Critical to breeding is availability of shallow aquatic habitat for egg laying and overwintering of larvae and paedogens. Adults may use damp upland or riparian habitats. The best habitats include access to ponds in areas where there is abundant vegetation and limited or absent predatory fish populations. In Osoyoos Lake these habitats exist in the limited remaining riparian wetlands, for example in Haynes Point Provincial Park, and in the downstream riparian areas maintained by outflows from Zosel dam. They will benefit from lake level management that keeps riparian soils moist, promotes wetlands and minimizes shoreline erosion.

6.1.1 Western Painted Turtle (*Chrysemasy picta*)

The primary habitat for Western Painted Turtles across their range are ponds, wetlands, slow moving streams and stands of emergent vegetation in these habitats (Stebbins 2003). The Western Painted Turtle is on the B.C. provincial blue list and a U.S. Fish and Wildlife Service Species of Concern. This means they are considered vulnerable to habitat loss, and susceptible to human and natural disturbances. Hatchlings may require shallow aquatic habitat, but little specific information is available (Gervais et al. 2009). The turtle is considered to have high compatibility with current levels of development in its home range, as long as certain criteria are met. The major challenges to turtle populations are road mortality during seasonal migrations from winter to summer habitat, availability of appropriate nesting grounds, and proximity of upland nesting areas to permanent ponds or lakes. Key best management practices to conserve turtle habitat include wetland preservation and maintaining buffers of undisturbed native vegetation around and adjacent to the lake (Biolinx Environmental Research Ltd and E. Wind Consulting. 2004). Lake level management that promotes wetland conservation and minimizes erosion will meet these goals.

6.1.1 Yellow-Breasted Chat (*Icteria virens*)

The Yellow-Breasted Chat is an 'identified wildlife' species, meaning it is designated by the Deputy Minister of Environment in B.C. as requiring special management considerations (Area A Habitat Mapping project 2003). The Okanagan valley and especially the region near the Similkameen River is its primary breeding range (Warman et al. 1998). This bird's main habitat is dense, riparian thickets that are at low elevation and have damp, but not inundated soil (B.C. Environment 1997). Habitat loss has occurred in this region mainly due to the development of lake shoreline for housing and agriculture (South Okanagan Similkameen Conservation Partnership, 2006). However, existing habitat can be maintained by lake level management that promotes riparian vegetation growth and minimizes erosion. Long-duration flooding of riparian areas (more than several days) to the point that soils become anoxic and plants are stressed, as well as long draw-down periods that dry soil and allow invasive species establishment should both be avoided. The Yellow Breasted Chat is one of several species that would benefit from wetland maintenance and restoration.

6.3 Sensitive ecosystems and native plants

Sensitive ecosystems are ecologically fragile or at-risk portions of the landscape important to a wide variety of flora and fauna. They may be the primary habitat for threatened or endangered species, or they may be used by animals at specific times of the year or points in the lifecycle such as during migration or for spawning. Many of the sensitive ecosystems in the valley are terrestrial and arid such as the scrubland the Haynes' Lease Ecological Reserve (adjacent to the North end of Osoyoos Lake) was established to preserve. However there are several critical aquatic habitats associated with Osoyoos Lake. Beyond the lake itself there are two types of sensitive ecosystems potentially relevant to the management of Zosel dam: Wetlands and Riparian areas. Wetlands are non-forested areas where the water table is at or near the surface and include marshes wet meadows and shallow open water. Riparian areas are directly adjacent to lake or streamside and have significant seepage. These include shrub dominated shorelines, lake shores, beaches, floodplains and raised benches adjacent to rivers (Iverson et al. 2008).

The BC Ministry of Environment has identified four plant species as priority species to incorporate into a foreshore management protocol for Osoyoos Lake: short-rayed aster (*Symphyotrichum frondosum),* scarlet ammannia (*Ammannia robusta*), toothcup (*Rotala ramosior*), and small-flowered lipocarpha (*Lipocarpha micrantha*). These species are also listed as endangered by the Canada Species at Risk Act (SARA) (McIntosh 2010).

Hydrologic needs of these species include natural patterns of wetting and drying of near-shore habitat, and at the same time protection from wave action that can cause erosion or bury existing plants. For example, scarlet ammannia and sort-rayed aster require a regime including periods of spring flood to cause the plant to flower and periods of late summer drought when substrate is exposed and seeds germinate (BCRS 2008). Current management of B.C. lakes including Osoyoos does not sufficiently mimic the natural flood/drought cycle. At the same time, increase shoreline erosion has reduced habitat and allowed expansion of invasive plant populations. Historic extent of wetlands has not been mapped, but historic photographs compared with modern ones (Figures 4a and b) show a reduction in shallow pond and seasonally inundated wetland habitat (McIntosh 2010).

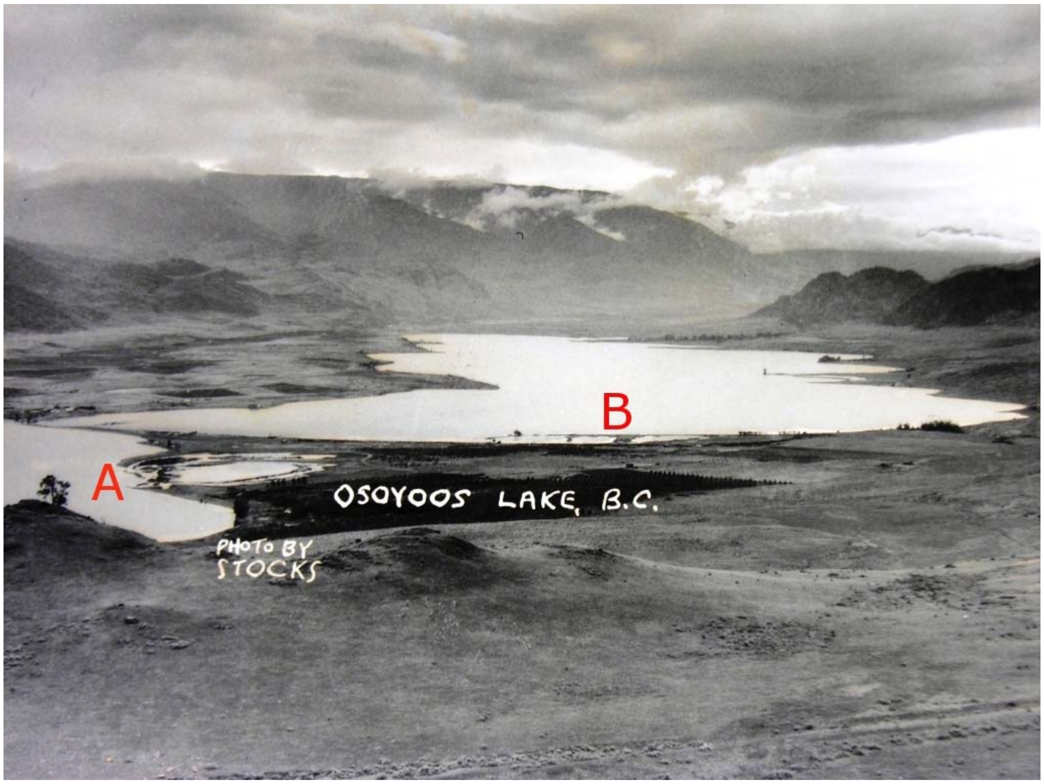

Figure 4a. A view of Osoyoos and part of Osoyoos Lake circa 1925 showing large ponded areas to the east of the long spit A and B (photographer unknown).

Figure 4b. A view of Osoyoos and part of Osoyoos Lake in 2002 showing development around the two ponded areas; the ponded area to the right has had many more buildings constructed along it since 2002 (McIntosh 2010).

A limited vegetation survey of foreshore habitats in 2009 found relatively few rare plants along the Osoyoos Lake shores (McIntosh, 2010) although Mica Spit on Osoyoos Lake, contains one of only 4 known sub-populations of toothcup in B.C. (BCRSS 2008). The 2009 survey report cited rapid fluctuation of lake levels as one potential cause of native species decline near the lake. Particularly, no near shore habitat was observed for either scarlet ammannia or toothcup and both species have only been observed on seasonally wet flats or alongside seasonally ponded depressions. It is suggested that the two species require calmer conditions for establishment than are found along wave-modified, active shorelines of Osoyoos Lake (McIntosh 2010).

Recovery plans for the three species that have them (short rayed aster, scarlet ammannia, and toothcup) each cite the need for additional detailed population studies and experimental testing of tolerance for habitat conditions (BC Ministry of Environment. 2008a, 2008b, 2009). Ideally, historic, natural fluctuations in lake level would be mimicked to conserve habitat and promote seed production and germination. To the degree that this is not possible, these species may be protected from further decline by maintaining water levels extant populations have tolerated to this point, and conserving near-shore habitat by preventing further degradation due to wave action and rapid fluctuations of lake water levels. As more information is gained about population locations and hydrologic needs, this should be included in conservation planning.

6.4 Salmonids

Salmonid concern in Osoyoos Lake is two parts: 1) maintaining acceptable water quality in the lake for non-migrating populations and juvenile salmon using the lake as rearing habitat and 2) providing optimal flow to the downstream reach to promote spawning and redd maintenance for anadromous populations.

Optimal habitat conditions for cold water fishes generally involve temperatures below 20 ^{o}C and dissolved oxygen concentrations above 5 mg/L. The temperature and dissolved oxygen profiles for the three major basins of Osoyoos Lake for 2007 are shown in Figure 5. In 2007, all three of the basins exhibit thermal stratification in the summer time, where warm surface waters float on top of a cold, denser layer of bottom water this condition is common in reservoirs such as Osoyoos Lake (Barber et al., 2010b). Oxygen depletion is especially apparent in the two smaller Central and South Basins in the latter summer and fall. Anoxic conditions are a particular concern for salmonids such as kokanee, which require cold, well oxygenated waters.

Decay of organic matter in bottom waters can contribute to low dissolved oxygen levels in the summer and fall, which can negatively impact lake biota, including cold water fish. Low oxygen conditions can also perpetuate the internal recycling of nutrients already present within the lake. When water overlaying bottom sediments go anoxic (no oxygen) the recycling of nutrients leads to continued poor water, quality even after external sources for nutrients are controlled. Rather than relying on changes in dam operations to impact water quality, lake managers should focus on the continued control of nutrient loading to the lake and changes to internal cycling (see Barber et al., 2010b). Two common in-lake management strategies used to combat internal nutrient loading include sediment treatment with alum (aluminum sulfate) and lake aeration/oxygenation (Cooke et al., 2005) should be considered for Osoyoos Lake.

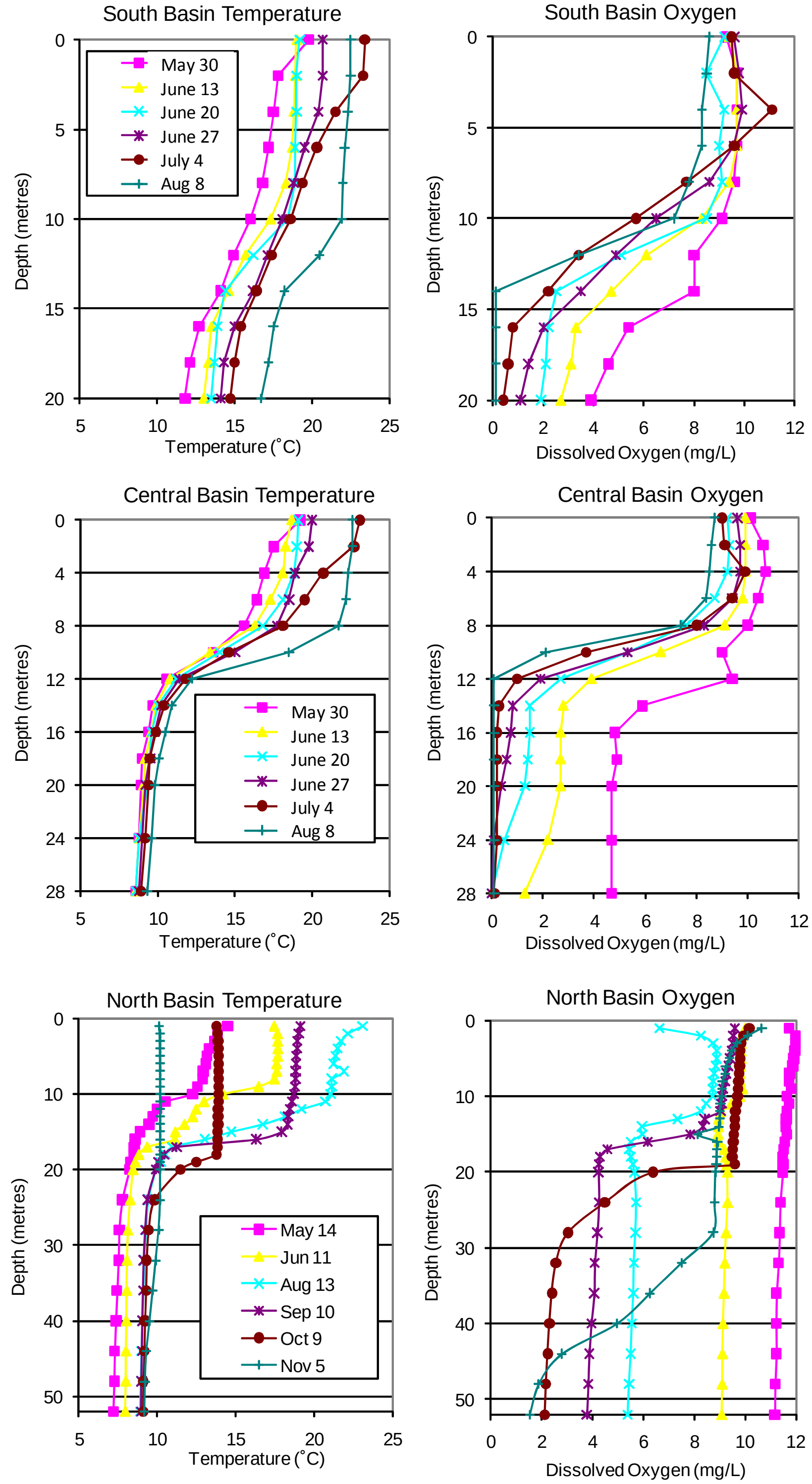

Figure 5. 2007 temperature and dissolved oxygen profiles in the North, Central and South Basins of Osoyoos Lake. North basin data from the BC Ministry of the Environment. Central and South Basin data from the Osoyoos Lake Water Quality Society.

The Zosel Dam Operating Procedures Plan (Ecology, 1990), created in cooperation with other agencies including the Board of Control and the BC Ministry of Environment, includes criteria for fishery flows and in-stream flows. Fishery criteria include the recommended flow for the passage of migrating fish at Zosel Dam. Together, fisheries and in-stream flow demands are the largest component of total water demand from Osoyoos Lake (Barber et al., 2010a). Depending on the month, they can be 4 to 10 times higher than other demands combined.

Following the existing plan, a discharge of ~300 cfs (9.43 m^3/s) is maintained when possible between October 1 and April 15 to allow egg/fry survival of Chinook salmon. This value is equivalent to 80% of the average October flow (1988-2007). For Steelhead spawning, incubation, and emergence, a discharge of ~500 cfs (13.6 m^3/s), which is equivalent to 80% of the average March flow (1987-2007), is recommended between March 1 and June 15. In April of drought years, the BC Ministry of Environment releases and additional volume of water up to 2,850 acre-feet (3.5 million m^3) from Okanogan Lake to be used to flush migrating sockeye smolts out of Osoyoos Lake. An attempt is made to maintain stream flow at 200 cfs (5.66 m^3/s) from June 15 to August 1 maintained for resident fish populations (Table 2) (Ecology, 1990). This corresponds with life cycle needs of the resident fish populations (Figure 6).

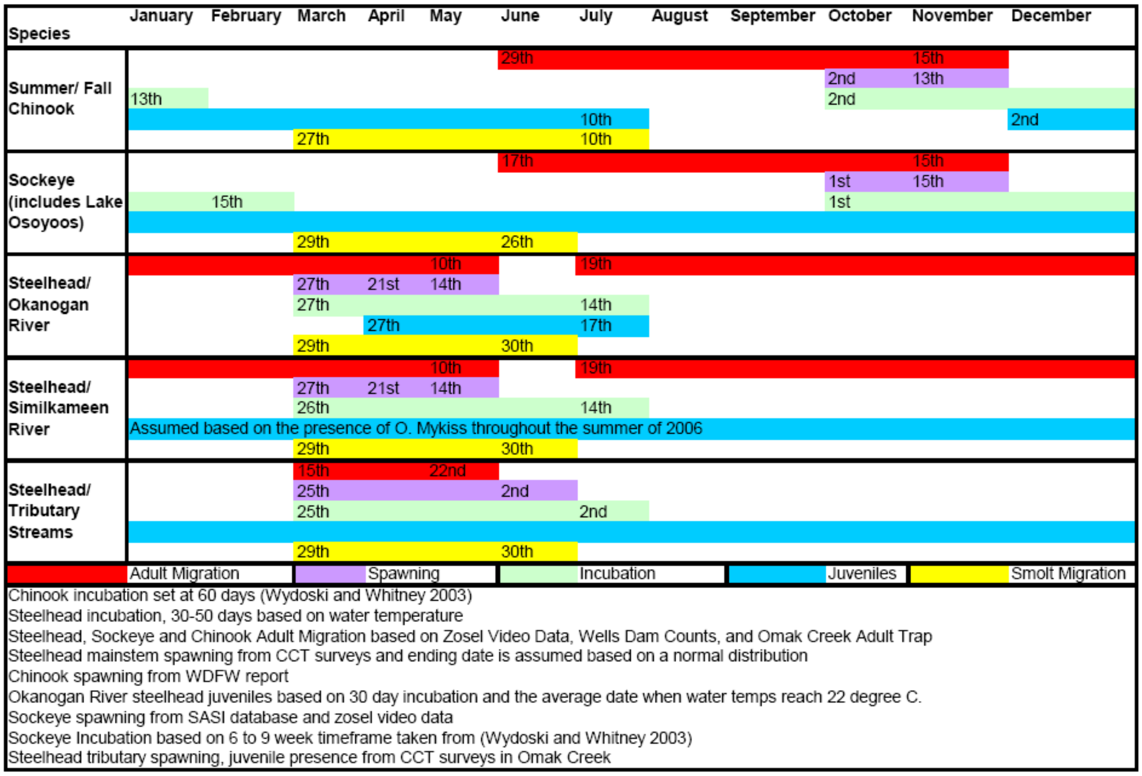

Figure 6. Fish periodicity for anadromous fish inhabiting the Okanogan and Similkameen Rivers. Prepared by Colville Tribes and Washington State Department of Fish and Wildlife, Anadromous Fish Division 2009.

Adequate discharge from the dam is necessary to submerge salmon spawning habitat in spring and fall and maintain flowing, well-oxygenated egg incubation conditions for the duration of the summer for steelhead and winter for Chinook and sockeye (Figure 6). At the same time, excessively high or fluctuating flows in this reach can cause sediment mobilization, erosion and the destruction of habitat and redds.

In 2009 a study was prepared for the Colville Confederated Tribes to determine the flows needed to optimize steelhead spawning in the Zosel dam to Similkameen confluence reach (LGL and PHES 2009). This study examined operational strategies for Zosel Dam to maintain optimal discharges for steelhead, Chinook and sockeye in the downstream reach. Under current conditions, they recommend that Zosel Dam outflow not drop below 350 cfs (9.91 m^3/s) to protect steelhead spawning and incubation, and fall-early winter Chinook spawning and incubation. This is close to the dam operating plan targets (Table 2) except during the period of June 15-August 1 when the current target is 200 cfs (5.33 m^3/s). (5.7). They also suggest it would be preferable to ensure stable or increasing flows during incubation, and higher flows from April to mid-June to facilitate sockeye smolts emigration from Osoyoos Lake. Under this scenario, releases from the lake could begin earlier (late March) and then higher discharges would extend longer (May to June 15) to meet lake level targets.

Due to concerns about the fluctuations in discharge in the Okanogan River on the east side of Driscoll Island and their potential impact on spawning and incubation of summer steelhead there, the Confederated Tribes of the Colville Reservation (CCT) have begun implementation of a flow management plan including the installation of cross channel mitigation structures in this reach. The structures were designed to constrain discharge from Zosel dam to the east side of Driscoll Island and prevent cross flow to the Similkameen River. Without the loss of water to the Similkameen, project planners think that minimum targets for steelhead spawning and incubation in the east channel will be met with flows of 150 cfs (4.2 m^3/s) from Zosel Dam (LGL, PHES 2009).

The cross channel structures also impacts recommendations for high flow limits from Zosel dam. Stream channel substrate in redds east of Driscoll Island is primarily gravel (84.6-89.3 %, LGL, PHES 2009) and limited data collected by CCT shows that threshold of motion is reached for these substrates at channel discharges over ~ 1,500 cfs (42.5 m^3/s). If the majority of the flow to the east channel comes from Zosel dam releases, as opposed to the Similkameen, then dam releases should be capped at ~1,500 cfs (42.5 m^3/s) to prevent destruction of salmon spawning habitat.

7 Recommendations for Additional Study

- A major difficulty in determining the importance of lake level for preserving sensitive wetland species as well as managing invasive wetland species is the lack of a definitive population maps with detailed elevation delineation for the areas surrounding the lake including locations immediately upstream. There are Designated Floodplain Area maps from the B.C. Ministry of Environment for the north side of the lake at with sub-meter scale contours (Okanagan River: Osoyoos to Penticton, Sheets 1-4 of 15, http:// www.env.gov.bc.ca/wsd/data_searches/fpm/reports/region3.html). This type of information, generated for the entire basin and paired with surveys of existing populations of sensitive species would be a very valuable tool for conservation planning. Other maps such as the US Geological Survey 1:24,000-scale topographic maps, either have broad contour intervals on the order of 5 m (16.4 ft) or do not include both the U.S. and Canada together using comparable habitat criteria (Sensitive Ecosystem Inventory, Madrone for Okanagan Regional Heritage Fund Society, 2003). The lake level elevation changes being considered are much smaller than 5 m and impact the entire perimeter of the lake. We recommend identification and mapping of critical wetland and riparian habitat at a much finer resolution than currently exists. This information would be very helpful to determine the degree to which areas could be expanded by realistic changes in dam operation, and what specific habitat and population benefits would be gained from this regulation.

- Wetland species in this basin are challenged by a history of land use changes, including wetland conversion, stream straightening and dam operation. Current population estimates of rare plants are based on only a few measurements and allow for very limited guidance on how water level impacts these species. We suggest detailed mapping of federally listed species of concern as well as a wildlife study to determine quantity and timing of use by animal species considered threatened or in decline. Beyond detailed mapping of current use, a map historic of wetlands, especially upstream of Osoyoos Lake, would be useful in determining if lake elevation or restoration could improve wetland (or salmonid) habitat there.

- While significant mapping of the area downstream of Zosel dam was done in conjunction with the development of mitigation structures, more information could be gained from additional work in that reach. A detailed flow maps of the area between Zosel dam and the confluence with the Similkameen, beginning with the existing fine-scale, high resolution digital elevation map, should be used to generate flow maps of this area at different dam discharge values and river stages. This could then be used to determine exact flow rates necessary to preserve and promote wetland and salmonid spawning habitat here.

- As the CCT flow management and mitigation structure plan is completed, it should be evaluated to determine the degree to which it alters low-end discharge requirements and high discharge erosion rates below Zosel dam. Dam discharge may be reevaluated using these criteria.

8 Conclusions

Lake levels may be fluctuated to control invasive species in the lake and riparian area. However, the levels required for this type of management are likely to cause serious problems for native plants and animals and will also be in conflict with other criteria for lake management such as shoreline maintenance and recreation needs. Using lake level management for invasive species control is not practical in this setting and alternative methods, such as biological or chemical controls, should be explored first.

Lake levels may impact riparian habitats important for sensitive species such as the Tiger salamanders and Yellow-Breasted Chat. Wetlands associated with Osoyoos Lake including those in Haynes Point Provincial Park may be maintained with a lake level plan that minimizes shoreline erosion and requires gradual fluctuations in lake level. This type of operation may also be beneficial for some rare native species and help slow the spread of some invasive plant species. More information on the current and historic locations of wetlands as well as a comprehensive and geographically specific wildlife study of wetland use by sensitive species would allow more detailed recommendations for wetland protection and expansion.

Because there are few lake shoreline spawning salmonids in Osoyoos Lake, discharge and not lake level is the most important criteria for maintaining healthy salmonid populations. However, suitable oxygen conditions must be maintained in the lake during the late summer to provide suitable habitat for cold water fishes. Management for water quality in the lake as outlined in Barber et al., 2010b will also promote this goal of improved fisheries. Currently, nutrient inputs are contributing to low oxygen conditions in deep water areas and internal recycling of nutrients perpetuates this problem. We suggest that well documented methods for controlling nutrients and improving oxygenation in deep waters be tried instead of management through lake level changes.

The fisheries and in-stream flow demands are the largest component of the total water demand from Osoyoos Lake and are critically important to the maintenance of salmonid spawning and incubation areas below Zosel dam. Dam managers should continue to strive to meet fisheries water demands recommended by the Washington Department of Fish and Wildlife. A target discharge range of 350 – 1500 cfs year-round should be used to maximize salmonid spawning habitat, maintain oxygenated conditions for redds during incubation while minimizing sediment transport and redd disturbance during high flows. This value is fairly close to the current operating plan guidelines, except in mid-summer. Mid summer discharge may need to be augmented to maintain optimal fish habitat downstream.

There are trade-offs between different management scenarios that will benefit various groups of species. Flow parameters should be set based on a prioritized list of goals for sensitive species and detailed habitat maps for these species.

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